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MEMORANDUM
November 1, 1983

To: Carl Nuechterlein

From: Art Johnson and Joe Joy

Subject: Water Quality of Crescent Bay Lake, August 1-2, 1983

INTRODUCTION

In response to your request, Joe Joy and I conducted a water quality survey of Crescent Bay Lake on August 1-2 earlier this year. The object of the survey was to document water quality conditions before the anticipated removal of the City of Grand Coulee STP outfall from the lake. Our findings are reported below.

STUDY AREA DESCRIPTION

Crescent Bay Lake is in the City of Grand Coulee, Grant County, by Grand Coulee Dam. The lake has a surface area of 90 acres, mean depth of 46 feet, and volume of 4,100 acre-feet (1). It was formed by diking an arm of Franklin D. Roosevelt Lake.

There are two inlets to Crescent Bay Lake - both artificial. The first is the City of Grand Coulee STP effluent stream, a .22 MGD discharge of primary-treated domestic sewage. The second consists of irrigation water pumped from Franklin D. Roosevelt Lake and diverted to Crescent Bay Lake by the Bureau of Reclamation (USBR) in an effort to improve the lake's water quality. The diversion has been in operation for three years and runs from April (or May) through September, typically at flows of 10 to 15 cfs (2).

The lake outlet is a culvert at the north end. To improve circulation within the lake, the USBR operates a pump station at the north end which draws lake water from a depth of 30 to 35 feet and discharges it through a pipe in the culvert. The USBR was unable to provide us with flow data for their pump.

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SURVEY METHODS

Figure 1 is a map of Crescent Bay Lake showing the inlets and outlets mentioned above, depth contours, and the four stations occupied during our water quality survey.

A 24-hour composite sample of the City of Grand Coulee STP effluent was collected beginning the afternoon of August 1 using a Manning automatic compositor (250 mL aliquots every 30 minutes) placed at the end of the chlorine contact chamber. This composite was split into separate samples for BOD_5, COD, specific conductivity, pH, turbidity, solids, and nutrient analyses. Grab samples were also taken on August 1 and 2 for temperature, D.O. (Winkler-azide modification), total chlorine residual (DPD kit), fecal coliform, oil & grease, and pH. Flow was determined from the plant's Parshall flume.

The USBR diversion into the lake was sampled by grab on the afternoon of August 2 for the parameters described above, except for chlorine residual and oil & grease. The staff gage was read for flow.

All lake samples were collected August 2. At each of the four stations shown in Figure 1 surface grabs were taken for D.O., fecal coliform, turbidity, total hardness, alkalinity, color, and nutrients. Vertical profiles of temperature, D.O.*, pH, specific conductivity, and oxidation reduction potential (ORP) were taken with a Hydrolab model "8000" and these data used to select depths for nutrient, Winkler D.O., and chlorophyll a/pheophytin a samples collected with a Van Dorn bottle. A Secchi disc reading was also taken.

All of the water samples taken during the survey were placed on ice immediately upon collection and returned to the WDOE Tumwater laboratory for analysis in accordance with EPA's *Methods for Chemical Analysis of Water and Wastes*.

RESULTS AND DISCUSSION

Data collected on the City of Grand Coulee STP effluent and USBR diversion are shown in Table 1. The treatment plant effluent was within NPDES permit limits except for chlorine residual. Water quality measurement on the USBR diversion showed it to be good-quality water low in BOD, bacteria, solids, and nutrients.

*The Hydrolab D.O. data are not reported due to instrument malfunction.

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The loads of BOD, NH_3-N, NO_3-N, T-PO_4-P, and TSS calculated from the above data were as follows:

	City of Grand Coulee STP Effluent	USBR Diversion
BOD_5 (pounds/day)	81	240
NH_3-N "	33	<.8
NO_3-N "	<.09	3.2
T-PO_4-P "	14	2.4
TSS "	62	160

The STP was responsible for about 89 percent of the nitrogen load and 86 percent of the phosphorus load to the lake. The USBR diversion appears to be the more important BOD and solids contributor, but this is by virtue of its volume and would have no adverse effect on the lake.

Table 2 shows the vertical water quality profiles made at each lake station. The data on temperature/D.O. and nitrogen/phosphorus are also shown in Figures 2 and 3, respectively, to better illustrate their change with depth.

The lake was well stratified. A surface layer (epilimnion) of about three meters in depth was supersaturated with oxygen and had a high pH -- conditions probably caused by plant photosynthesis. D.O. concentrations fell rapidly below depths of three meters and reached near-zero levels at 7 to 10 meters (hypolimnion). The oxygenated layer appeared to be deeper in the northern arm of the lake.

The epilimnion was depleted in nitrogen and high in phosphorus. Nitrogen, rather than phosphorus, appears to be the limiting nutrient in Crescent Bay Lake as indicated by the existing N:P ratios of less than 5 (3). Extremely high concentrations of ammonia and phosphorus were found in the hypolimnion. An H_2S odor was also noticeable. These high nutrient levels in conjunction with low N:P ratios suggest Crescent Bay Lake is in an advanced state of eutrophication (4).

The chlorophyll/pheophytin data in Table 2 are of questionable accuracy. It is possible that spatial and temporal patchiness or sampling errors were responsible for the wide differences in pigment concentrations seen in samples from different parts of this relatively small lake. It should be noted, however, that the WDOE Tumwater laboratory is aware of several as yet unresolved problems with the EPA chlorophyll/pheophytin method (5).

Results of analyses on surface grabs taken for other parameters are in Table 3. These data show the surface waters were clear and had essentially no fecal coliform bacteria. The average hardness and alkalinity were 75 mg/L and 73 mg/L, respectively. Color increased from 13 units at the north end of the lake to 21 units at the east end.

The timing of our survey did not coincide with an algal bloom. The high pH, moderate alkalinity, and very low free CO_2 values (as calculated from the alkalinity and pH data) indicate an environment in which mixed blue-green algae would dominate (3, 6) -- a further indication of advanced eutrophication.

Data from samples collected by WDOE on June 14, 1974, from the center of Crescent Bay Lake (see Table 4) are generally in agreement with the findings of our survey. These early data show larger concentrations of nutrients in the surface waters and lower concentrations in the bottom waters relative to our 1983 survey. This is at least partly due to the 1974 samples having been collected earlier in the growing season.

A second source of historical information on the lake is USBR data on temperature, D.O., BOD, and secchi depth from the summer of 1979 as supplied to us by R.E. Ethridge, project manager. These data are summarized in Table 5. Note that D.O. was already almost zero in the middle depths of the lake at the beginning of their monitoring program in May. Also of interest are the relatively high BOD in some samples.

The USBR potentially flushes Crescent Bay Lake at a rate of 0.9 - 1.1 times per year, assuming withdrawal is approximately equal to the average amount of water diverted into the lake, 12.5 cfs, over the five- to six-month period. The locations of USBR points of diversion and withdrawal may isolate the eastern arm and deeper hypolimnic waters from the flushing pattern. A deeper intake would include more of the lake in the flushing pattern, as well as remove more nutrients per volume withdrawn.

The addition of low-nutrient Lake Roosevelt water has a diluting effect on nutrient-rich Crescent Bay Lake. The diversion water is also lower in pH and higher in free CO_2 than the lake water. These factors work against growths of blue-green algae.

USBR should be encouraged to continue their activities in Crescent Bay Lake. Perhaps an arrangement could be made for USBR and WDOE to jointly monitor the progress of the lake through periodic sampling. A single, mid-lake station sampled from spring through early fall to profile temperature, D.O., nutrients, and algal biomass is recommended.

The nutrient loading from the Grand Coulee STP is undoubtedly the primary cause for water quality problems in Crescent Bay Lake. Prior to the efforts of the USBR, the lack of flushing action and circulation

probably further aggravated the situation. We are not able to estimate how well or how soon the lake would recover once the STP effluent is removed.

There are potential problems in relying on the data from our survey as the sole basis for a "before and after sewage diversion" comparison of water quality in Crescent Bay Lake. Although the survey involved considerable expenditure of field and laboratory effort -- about 350 individual water quality related measurements were made -- there are only two areas where the survey results are likely reference points against which to judge improvements. These are (1) the extent of the anaerobic layer and (2) nutrient concentrations. Such a comparison is likely to be complicated by seasonal changes in these parameters. If a not very rigorous demonstration of improvement is required, our data may suffice.

AJ:JJ:cp

Attachments

REFERENCES

1. WDOE/USGS, 1976. Reconnaissance Data on Lakes in Washington. Water-Supply Bulletin 43, Vol. 6

2. Cutlow, J., USBR, personal communication.

3. EPA, 1982. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants - Part 2. EPA-600/6-82-004b.

4. Welch, E.B., 1980. *Ecological Effects of Waste Water*. Cambridge Univ. Press.

5. McCall, M.F., WDOE Tumwater laboratory, personal communication.

6. Lind, O.T., 1979. *Handbook of Common Methods in Limnology*. The C.V. Mosby Co.

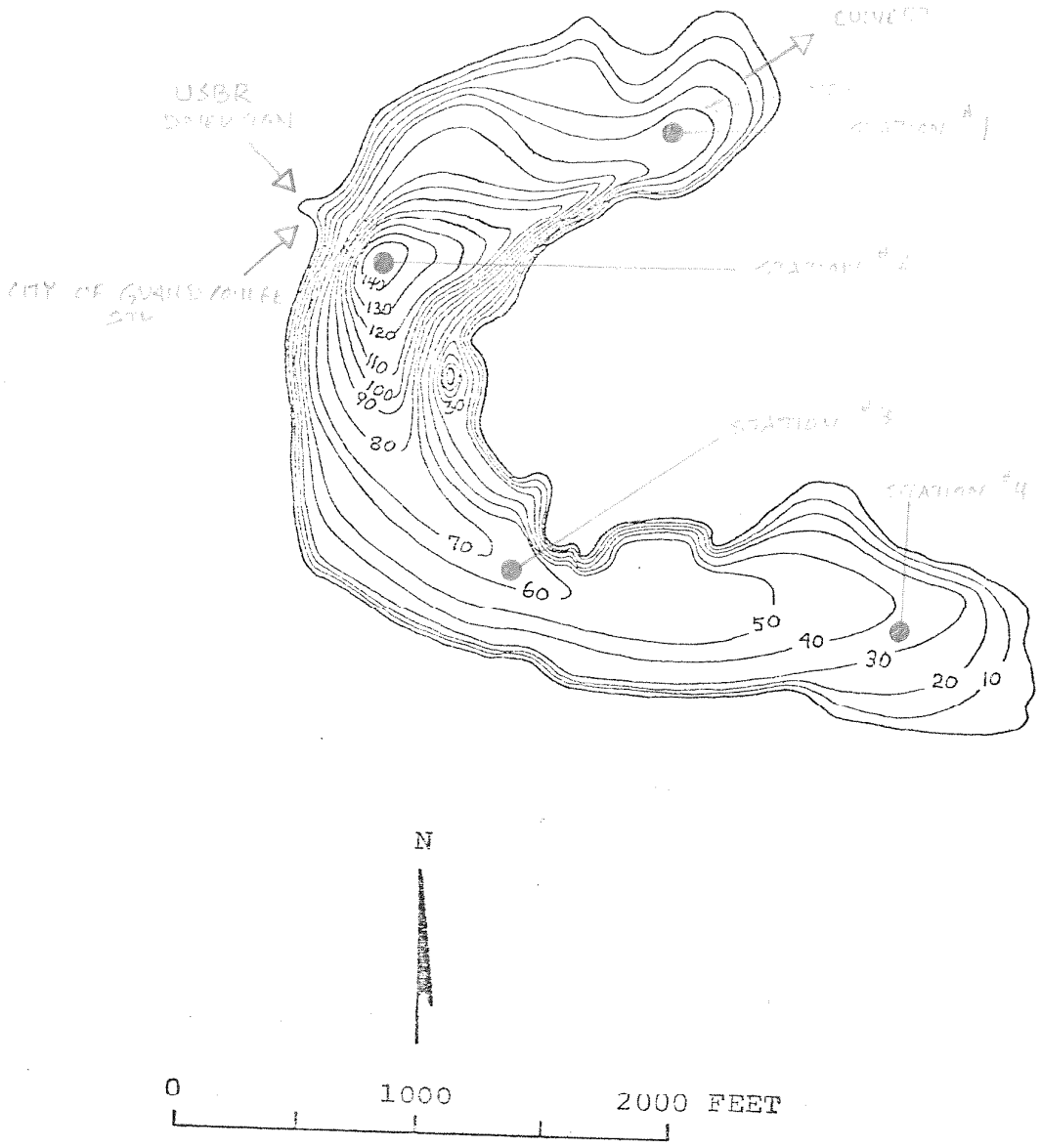

Figure 1. Crescent Bay Lake, Grant County, Washington showing inflows, outflows, bathymetry, and WDOE water quality stations sampled August 2, 1983 (depths in feet). [From: WDOE/USGS 1976. Reconnaissance Data on Lakes in Washington - Vol. 6]

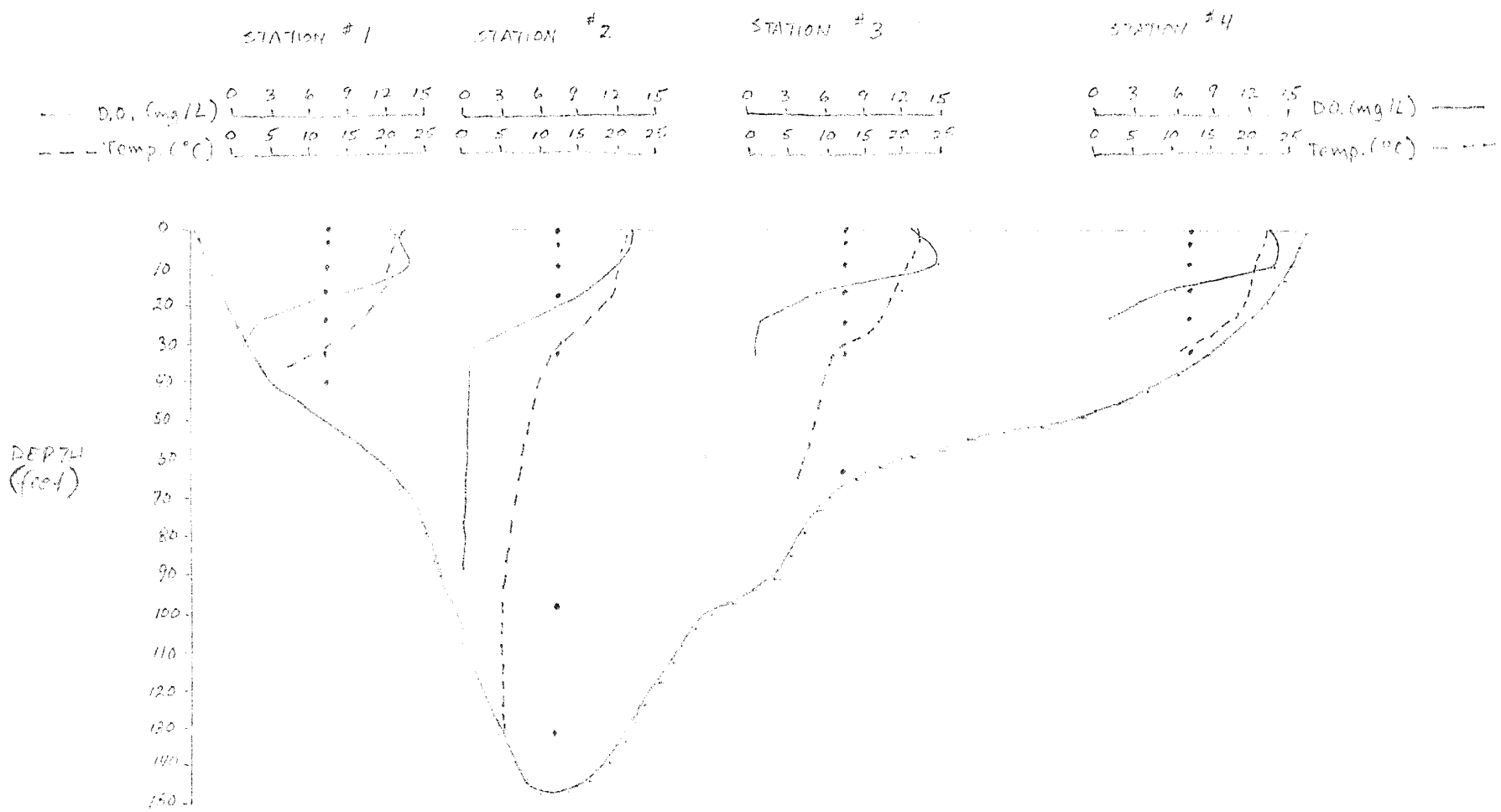

Figure 2. Temperature and D.O. profiles in Crescent Bay Lake, August 2, 1983.

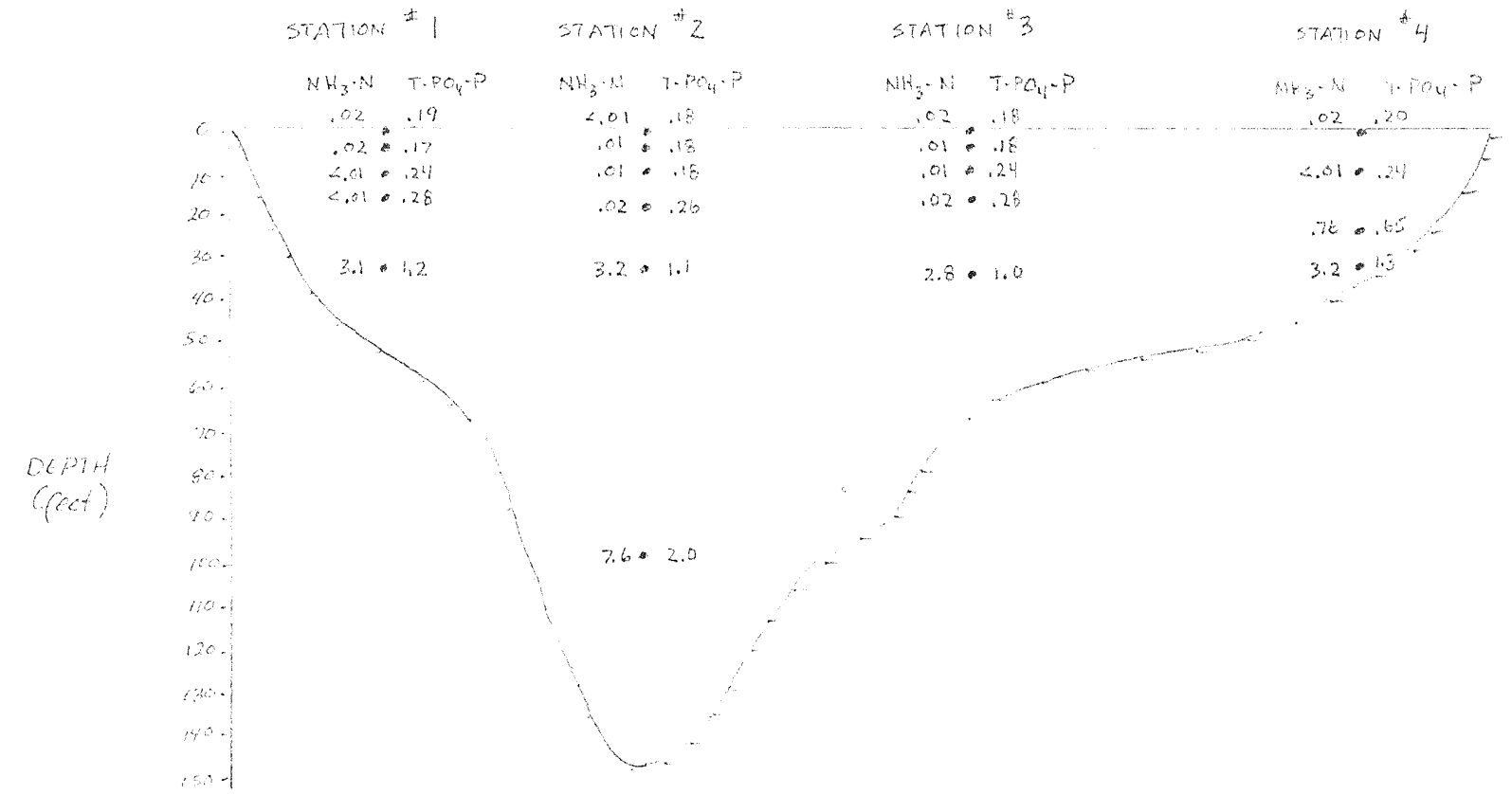

Figure 3. NH_3-N and T-PO_4-P profiles in Crescent Bay Lake, August 2, 1983 (concentrations in mg/L).

Table 1. Water quality of inflows to Crescent Bay Lake, August 1-2, 1983.

Parameter	City of Grand Coulee STP Effluent*	NPDES Permit Limits	USBR Diversion**
Flow (MGD)	.22		9.7
BOD_5 (mg/L)	44	80	3 Est.
Sp. Cond. (μmhos/cm)	632		122
pH (S.U.)	7.4** 7.6	6.5-8.5	7.8
Temperature (°C)	22.7** 20.7** 22.5**		17.0
D.O. (mg/L)	2.7** 2.2**		9.5
Tot. Chl. Res. (mg/L)	1.5** 1.5**	.1-.5	
F. Coli. (#/100 mL)	380** 8,700** 4,300**		<1 <1
Turbidity (NTU)	32		1
Total Solids (mg/L)	430		130
TNVS (mg/L)	310		94
TSS (mg/L)	34	80	2
TNVSS (mg/L)	7		1
NH_3-N (mg/L)	18		<.01
NO_2-N (mg/L)	<.05		<.01
NO_3-N (mg/L)	<.05		.04
O-PO_4-P (mg/L)	6.2		.03
T-PO_4-P (mg/L)	7.8		.03
Oil & Grease (mg/L)	4** 18**		
COD (mg/L)	140		14

*24-hour composite unless otherwise noted.
**Grab samples.
Est. = Estimated

Table 2. Vertical water quality profiles in Cascade Bay Lake, August 2, 1983.

Depth (meters)	Temp.* (°C)	D.O.** (mg/L)	D.O. Sat. (%)	pH* (units)	Cond.* (µmhos/cm)	ORP* (mV)	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	O-PO_4-P (mg/L)	T-PO_4-P (mg/L)	Chlor. a† (mg/L)	Pheo. a† (mg/L)
					Station #1 - N. End								
Surface	22.1	13.8	162	9.7	188	77	.02	<.01	<.01	.16	.19	6.2	2.3
1 (meters)	22.0	13.3	156	9.7	187	81	.02	<.01	<.01	.16	.17		
3 "	20.7	14.1	162	9.5	182	97	<.01	<.01	<.01	.18	.24		
5 "	19.5	8.7	98	9.1	187	113	<.01	<.01	<.01	.21	.28		
7 "	17.4	2.0	22	7.9	214	146	--	--	--	--	--		
10 "	11.6	0.5	5	7.2	278	-65	3.1	<.01	<.01	1.0	1.2		
12 "	7.9	--	--	7.1	279	-111	--	--	--	--	--		
					Station #2 - Center								
Surface	22.2	13.1	154	9.7	201	134	<.01	<.01	<.01	.16	.18	.7	4.6
1 (meters)	22.2	13.3	156	9.7	201	134	.01	<.01	<.01	.18	.18		
3 "	21.3	12.9	150	8.5	190	138	.01	<.01	.01	.16	.18		
5 "	20.0	9.1	103	9.2	193	149	.02	<.01	.02	.24	.26		
10 "	11.2	0.2	2	7.8	273	-29	3.2	<.01	.01	1.1	1.1		
30 "	5.8	0	0	7.1	327	-90	7.6	<.01	<.01	2.0	2.0		
40 "	5.7	--	--	6.9	344	-128	--	--	--	--	--		
					Station #3 - Elbow								
Surface	22.4	13.2	155	9.7	192	72	.02	<.01	<.01	.16	.18	4.0	1.2
1 (meters)	22.4	13.8	162	9.7	193	76	.01	<.01	<.01	.16	.18		
3 "	21.8	15.1	178	9.7	192	80	.01	<.01	<.01	.17	.24		
5 "	19.2	5.8	64	9.1	193	109	.02	<.01	<.01	.24	.28		
7 "	17.1	0.4	4	7.9	224	149	--	--	--	--	--		
10 "	11.4	0.2	2	7.6	284	-49	2.8	<.01	<.01	1.0	1.0		
20 "	6.2	--	--	7.3	318	-93	--	--	--	--	--		
					Station #4 - E. End								
Surface	22.3	13.5	159	9.8	191	51	.02	<.01	<.01	.16	.20	1.2	8.6
1 (meters)	22.1	14.2	167	9.8	192	59	--	--	--	--	--		
3 "	21.3	14.2	165	9.7	191	67	<.01	<.01	<.01	.18	.24		
5 "	20.8	5.5	63	9.4	192	84	--	--	--	--	--		
7 "	18.0	0.9	10	8.0	213	115	.76	<.01	<.01	.56	.65		
10 "	11.6	--	--	7.5	282	-77	3.2	<.01	<.01	1.3	1.3		

*Hydrolab measurements; ORP = oxidation reduction potential
**Winkler
† = Composite of equal volumes from surface, 1m, 3m, and 5m.

Table 3. Miscellaneous water quality data from surface grabs in Crescent Bay Lake, August 2, 1983.

	Station #1 N. End	Station #2 Center	Station #3 Elbow	Station #4 E. End
Turbidity (NTU)	2	2	2	3
Secchi depth (feet)	7.5	9	8	5.5
Fecal coliform (#/100 mL)	<1	<1	<1	<1
T. Hardness as $CaCO_3$ (mg/L)	73	77	77	73
Alkalinity as $CaCO_3$ (mg/L)	74	72	75	70
Color (units)	13	13	17	21

Table 4. WDOE historical data on Crescent Bay Lake from samples collected June 14, 1974 (in mg/L unless otherwise indicated).

Date	June 14, 1974	
Time (hours)	0945	0950
Depth (feet)	3	144
Total Nitrate (N)	0.27	0.04
Total Nitrite (N)	0.03	0.00
Total Ammonia (N)	0.29	3.8
Total Organic Nitrogen (N)	0.91	0.80
Total Phosphorus (P)	1.5	3.2
Total Orthophosphate (P)	1.5	3.1
Specific Conductance (micromhos)	420	580
Water Temperature (degrees C)	21.2	4.1
Color (platinum-cobalt units)	5	10
Secchi-disc Visibility (Ft.)	14	
Dissolved Oxygen	9.9	0.1
Number of Fecal Coliform Samples		3
Fecal Coliform, minimum (col/100 mL)		1
Fecal Coliform, maximum (col/100 mL)		6
Fecal Coliform, mean (col/100 mL)		4

Source: Reconnaissance Data on Lakes in Washington. WDOE Water Supply Bulletin 43. Vol. 6

Table 5. USBR data on Crescent Bay Lake (R.E. Ethridge, Grand Coulee Project Office).

	Depth	Sampling Date	Temperature (°C)	D.O. (mg/L)	BOD_5 (mg/L)	Secchi Depth (meters)
"Center of Lake"	Surface	5/23/79	19	11.2	--	6+
	Middle[a]	"	7.8	0	--	
	Bottom[b]	"	7.6	0	--	
	Surface	6/27/79	24.0	9.8	2.9	6
	Middle	"	8.5	0	13.4	
	Bottom	"	9.0	0	15.5	
	Surface	7/16/79	23.5	15.5	2.1	2.3
	Middle	"	8.5	0	10.7	
	Bottom	"	8.0	0	10.1	
	Surface	8/23/79	23.8	13.1	2.9	5
	Middle	"	9.8	0	12.0	
	Bottom	"	8.9	0	14.3	
	Surface	9/26/79	18.8	9.6	2.7	3
	Middle	"	9.0	0.0	13.5	
	Bottom	"	6.0	0.0	9.4	
"East End of Lake"	Surface	5/23/79	19.4	11.1	--	6+
	Middle	"	8.4	.5	--	
	Bottom	"	6.8	0.0	--	
	Surface	6/27/79	23.0	9.8	2.2	6
	Middle	"	8.5	0	5.0	
	Bottom	"	7.5	0	10.0	
	Surface	7/16/79	23.5	16.6	2.2	2.3
	Middle	"	20.0	6.4	2.1	
	Bottom	"	9.0	0.0	3.0	
	Surface	8/23/79	23.8	12.8	1.7	5
	Middle	"	7.0	1.7	3.9	
	Bottom	"	5.4	2.1	6.8	
	Surface	9/26/79	18.9	9.9	2.4	3
	Middle	"	18.5	9.3	6.0	
	Bottom	"	8.0	0	4.2	

[a] "about 6 meters"

[b] "about 10 meters"